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EXPLOITING THE UTILITY OF SPACE-BASED ENVIRONMENTAL SURVEILLANCE SYSTEMS AT THE OPERATIONAL LEVEL OF WAR

by

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A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

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15.Abstract: The ability to assess the physical environment of the battlefield and understand its implications on the outcome of military operations is an integral part of the operational commander's planning and decision making processes. Today, accurate environmental intelligence, particularly in the areas of weather observation and terrain characterization, is almost exclusively accomplished through the use of space-based surveillance systems. The analysis of near real-time, satellite data in the form of digital, multispectral imagery (MSI) can be utilized to provide precise information on weather systems, atmospheric profiles, nearshore beach surveys, bathymetry, land classification schemes, terrain contouring and topography, hydrological evaluations, and much more. For today's Joint Task Force commanders (CJTFs), the exploitation of this environmental intelligence in support of operations at the theater level of war has a direct bearing on mobility, maneuver, deception, operational fires and reconnaissance (RECCE). Specific military applications of MSI include; disaster assessment; land lines of communication (LOCs) identification and interdiction; camouflage, concealment and deception (CC&D) detection; flight planning; and strike targeting. Not surprisingly, the utility of MSI applications tailored to supporting CJTFs spans the entire spectrum of conflict, from operations other than war (OOTW) scenarios such as humanitarian relief assistance and noncombatant evacuations (NEOs) to wartime amphibious assaults and major regional contingencies (MRCs).

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ABSTRACT

The ability to assess the physical environment of the battlefield and understand its implications on the outcome of military operations is an integral part of the operational commander's planning and decision making processes. Today, accurate environmental intelligence, particularly in the areas of weather observation and terrain characterization, is almost exclusively accomplished through the use of space-based surveillance systems. The analysis of near real-time, satellite data in the form of digital, multispectral imagery (MSI) can be utilized to provide precise information on weather systems, atmospheric profiles, nearshore beach surveys, bathymetry, land classification schemes, terrain contouring and topography, hydrological evaluations, and much more. For today's Joint Task Force commanders (CJTFs), the exploitation of this environmental intelligence in support of operations at the theater level of war has a direct bearing on mobility, maneuver, deception, operational fires and reconnaissance (RECCE). Specific military applications of MSI include; disaster assessment; land lines of communication (LOCs) identification and interdiction; camouflage, concealment and deception (CC&D) detection; flight planning; and strike targeting. Not surprisingly, the utility of MSI applications tailored to supporting CJTFs spans the entire spectrum of conflict, from operations other than war (OOTW) scenarios such as humanitarian relief assistance and noncombatant evacuations (NEOs) to wartime amphibious assaults and major regional contingencies (MRCs).

INTRODUCTION

Throughout history, the extent of familiarity with the physical environment of the battlefield has been a key factor in influencing the "fog and friction" of war. From Operation OVERLORD in World War II, where the commencement of the Normandy invasion hinged upon ascertaining the latest status of the weather, to Operation URGENT FURY in 1983, where mobility and maneuver in Grenada were complicated by the lack of standardized, accurate maps, the importance of acquiring an intimate understanding of the environment has been critical in gaining superior battlefield situational awareness.[1] Today, where combat is faster paced and more lethal than ever before, it is the attainment of space superiority that guarantees the most complete familiarity with the physical environment.

It is no secret that the U.S. led coalition of forces that convincingly defeated Iraq in Operation DESERT STORM was helped immeasurably by its absolute and utter dominance of space. Precise navigation, unprecedented communications connectivity and an impressive missile defense umbrella were all worthy capabilities that resulted from holding the "high ground" of space.[2] A lesser publicized but equally important capability stemming from the Coalition's space control was the exploitation of uninterrupted, remotely sensed weather and terrain data that would have otherwise been difficult to obtain in such hostile, unfamiliar territory.

The influence of space-based, environmental assessment on current Joint Task Force (JTF) operations has not waned since the Gulf War. In fact, recent advancements in the processing and analysis of satellite multispectral imagery (MSI) have allowed commanders to

become even more familiar with the physical environment of the theater of operations. Specifically, accurate, near real-time weather monitoring and precise terrain characterization can now be realized through various MSI analysis techniques. Such environmental intelligence can play a significant role in influencing a JTF commander's (CJTF) decisions regarding mobility, maneuver, deception, operational fires and operational reconnaissance (RECCE). Today, military applications of MSI span the entire spectrum of conflict. For the CJTF, the exploitation of these applications is fundamental to enhancing overall "battlefield visualization" and a critical step in ensuring the success of any major joint operation.

SATELLITE SURVEILLANCE CAPABILITIES

The key to exploiting remotely sensed environmental data primarily lies in the technique of MSI processing. The U.S. DOD currently employs both civil and military MSI satellite systems to provide detailed imagery for weather monitoring, terrain characterization and various other uses. Without delving into technicalities, today's satellite sensors are capable of collecting, digitally processing and electronically transmitting environmental data to any eligible ground receiving station.[3]

Meteorological observation from space is not a new concept. However, recent improvements to satellite sensors and receiving stations have made current weather monitoring and forecasting more capable and timely than ever before. Civilian satellites including GOES and TIROS-N, along with the U.S. military's DMSP, continually provide accurate information on synoptic scale weather systems,

smaller-scale cataclysmic weather events, precipitation, cloud cover, vertical atmospheric temperature profiles and wind conditions.[4] Presently, the two most utilized MSI platforms that are capable of providing detailed mapping and terrain characterization are Landsat, which is operated by the United States and SPOT, a French controlled satellite. Resolutions as precise as 13 meters are possible when the commercially available data from these two platforms are merged into composite imagery.[5] For comparison, U.S. DOD sensors mounted on RECCE aircraft are capable of discerning resolutions of 0.25 meters.[6]

While resolution is certainly important for environmental intelligence gathering, the true value of MSI is ultimately realized when certain spectral band combinations are simultaneously measured and compositely merged for a given sampled scene. The resulting imagery has the capability to accurately discriminate features or properties that are otherwise not visible to the human eye such as moisture content, vegetation stress, and heat intensity.[7] Not surprisingly, the applications of recording these normally invisible characteristics on high resolution imagery are numerous. Today's military commanders unhesitatingly take advantage of the worldwide coverage capability, the near real-time delivery of data, and the passive, non-intrusive nature of MSI satellites to collect intelligence on the physical environment at the theater level.

INCORPORATING ENVIRONMENTAL DATA INTO BATTLEFIELD VISUALIZATION

The U.S. Army's over-arching concept of battlefield visualization requires commanders to have:

> "... a comprehensive view of the battlefield - a view which reduces uncertainty, minimizes risk ... and facilitates the

decisive employment of combat power."[8]

In addition,

> "All battlefields require commanders to make and execute decisions faster than the enemy. Therefore, the commander must always strive to optimize time available."[9]

There is no better example of simultaneously adhering to both of these tenets than the use of space-based assets providing near real-time analysis of the battlefield environmental conditions. In fact, gaining a clear understanding of weather and terrain effects is one of the commander's primary tasks during the initial intelligence preparation of the battlefield (IPB) phase of his overall planning and decision making process.[10]

For the CJTF, modern MSI techniques can provide a wealth of decisive information on the physical environment of the theater of operations. Satellite imagery of the synoptic weather picture can sometimes be the only source of weather observation in hostile or isolated areas. Remotely sensed imagery is also a valuable tool for areas in which the potential battlefield is not already covered by available topographic maps. In addition, it can supplement or replace pre-existing outdated or unreliable maps. Imagery scales run the gamut from broad area, theater level analyses, such as a 1:250,000 scale used for area orientation, to detailed snapshots of features that may be critical for tactical missions.

Automated terrain categorization (TERCAT) imagery provides a distinct, color-coded classification of landcover in categories such as urban, water, bare soil, crops, wetland vegetation and coniferous trees. A technique known as MSI sharpening can actually improve Landsat's normal 30 meter resolution to 1 meter by merging its data

with higher resolution panchromatic (black and white) imagery.[11] Combining sharpening with TERCAT imagery can reveal true vegetation plot, land cover, hydrology, land lines of communication (LOCs), obstacles, cover and concealment, and mobility corridors. With this type of environmental intelligence, the CJTF can generate credible, operational level "trafficability" and maneuver schemes, as well as enemy order of battle and force emplacement estimates. When TERCAT is used in conjunction with the Defense Mapping Agency's complete global elevation data base called Digital Terrain Elevation Data (DTED), explicit three-dimensional (3D) images called perspective views can be created.[12] With the ability to exaggerate vertical features for emphasis, these graphic 3D images can literally be used to reproduce a realistic, virtual operating environment for mission planning and rehearsal.[13] Advancements in the analysis of MSI such as TERCAT, sharpening, DTED and perspective views are invaluable to the overall process of IPB. They offer the ability to realistically view and analyze battlespace as well as actually rehearse the mission. The commander who has the capability to do this can better exploit the well known principles of war and engage the enemy with minimal risk and ultimate cost.

APPLICATIONS FOR THE CJTF

Overall, there are strategic, operational and tactical level applications of MSI. Ideally, the warfighters on the battlefield should have the ability to analyze real-time MSI for their own utility. Unfortunately, exorbitant costs, the cumbersome nature of current MSI processing facilities and a shortage of specially trained

and experienced analysts currently restrict the direct control of MSI to the CINC level. With such limited availability, the exploitation of MSI essentially remains a theater level function and must be managed appropriately in order to realize its full potential.

Much has been done recently to facilitate the dissemination of MSI environmental intelligence to CJTFs. In the realm of technology, highly versatile and portable shipboard and ground based AN/SMQ-11 receivers, with direct downlink capability, now allow CJTFs to routinely receive real-time images of DMSP generated, local weather data.[14] Similarly, during DESERT STORM, a prototype, van-based, photo map production facility was set up in Riyadh, Saudi Arabia which provided an in-theater map generating capability, albeit it took 45 days to become operational.[15]

Other efforts in overcoming the limited availability of MSI intelligence have focused on eliminating organizational infrastructure liabilities. First and foremost, it is hoped that the recently approved consolidation of the nation's diverse imaging organizations into a centrally directed National Imaging and Mapping Agency (NIMA) will be a first step in streamlining access to support along with eliminating the present redundancy of space-based imagery programs. At the theater level, the establishment of National Intelligence Support Teams (NISTs) should translate into a more focused application of MSI and expedite dissemination of environmental intelligence to support a myriad of CJTF decisions relating to, among others, schemes of maneuver, selection of fires and force disposition alternatives at the operational level.

Obviously, the trend to facilitate access to formerly national

level, space-based environmental intelligence assets continues to be emphasized. Today's operational commanders and their J2 staffs are infinitely more knowledgeable on what type of environmental intelligence is available and more importantly, on exactly how it can be exploited in the quest to gain unprecedented visualization of the battlefield.

As noted previously, MSI applicability encompasses the entire spectrum of conflict. In operations other than war, ranging from humanitarian assistance and noncombatant evacuation operations (NEOs) all the way to amphibious assaults and full fledged major regional contingencies (MRCs), there is a practical use for MSI.

DISASTER RELIEF AND HUMANITARIAN ASSISTANCE MISSIONS

Consider the case of a JTF tasked with providing disaster relief in order to alleviate the effects of major flooding. MSI can provide an up to the minute, hydrological analysis with imagery detailing the exact extent of flood boundaries. In varying scales, ranging from broad area coverage to smaller scale feature identification, these images can provide a definitive assessment of the severity of flooding and are especially valuable when used in conjunction with pre-flood MSI data.[16] In addition, land LOCs such as highways, bridges and rail systems that are no longer "trafficable" due to flooding are easily recognizable. Altogether, this remotely sensed environmental information allows the CJTF to rapidly and efficiently apportion his assets commensurate with either the imminent danger of further flooding or with the priority of reconstruction. Not surprisingly, the aforementioned use of MSI also lends itself to assessing the extent of oil slicks resulting from major maritime

accidents.

In another example of providing humanitarian assistance, JTFs may be called upon to control and extinguish rampant forest fires. MSI can furnish accurate, large scale fire boundary information, day or night, regardless of overlying smoke obscuration by clearly contrasting burned and burning areas with live vegetation.[17] Incidentally, this technique was highly effective in pinpointing the locations of the burning Kuwaiti oil wellheads that were completely obscured by the thick black smoke that blanketed the entire region during DESERT STORM. By utilizing composite MSI, individual wellhead fires were visible as bright orange dots which allowed for the exact counting of individual fires.[18] As before, this type of environmental intelligence is indispensable to the CJTF for executing force and equipment disposition.

NONCOMBATANT EVACUATION OPERATIONS (NEOs)

There are several applications of MSI to NEO support. The JTF assigned to conduct a NEO may not have the luxury of communications connectivity with the evacuees, extensive planning time, modern debarkation facilities or even a cooperative host government. Additionally, the "on the shelf" version of the NEO may be out of date and may not indicate the most favorable debarkation points, landing zones or evacuation routes. For a NEO under these conditions, remotely sensed MSI can furnish rapid, specific intelligence on the environment where the evacuation will take place. In particular, on scene weather, land LOCs, helicopter landing zones (HLZs), terrain categorization can all be evaluated for suitability.

Typically, a deployed Marine Expeditionary Unit, Special

Operations Capable (MEU(SOC)) is the force of choice for such time constrained NEOs. The CJTF can provide the MEU(SOC) with a plethora of worthwhile environmental information. First and foremost, the prevailing weather on scene can be monitored to ensure it remains within aviation safety parameters. Low-level flight in an unfamiliar urban environment is dangerous enough without the complication of unexpected low ceilings. As previously discussed, the weather picture can be gleaned from MSI, regardless of whether local observations can be communicated from on-scene. In addition, TERCAT imagery is a valuable tool in the analysis of mobility relating to land LOCs that may be chosen as egress routes to HLZs. The ability to evaluate precise distances, general "ruggedness" and the existence of choke points that may impede the evacuation route is vital to the NEO planners on the JTF staff.

For a heliborne evacuation, HLZs and flight paths will, by necessity, be identified and selected on short notice. High resolution MSI scenes coupled with satellite radar altimeter data can distinguish the most suitable HLZs in terms of area, slope and obstacle clearance. TERCAT imagery can also positively identify the more preferred, hard surface HLZs.[19] Helicopter approach and departure routes are also critical for ensuring safety and surprise during a potentially hazardous NEO. The perspective views generated from MSI and the DTED data base can be used to identify the safest, most expeditious flight routes. Realistic 3D imagery that provides actual headings and altitudes can be reproduced with little advance notice. With more time available, the entire operation can actually be rehearsed by utilizing authentic "flythru" simulations.[20]

AMPHIBIOUS ASSAULTS

Environmental assessment is essential for proper amphibious assault planning at the JTF level. Comprehensive knowledge of oceanographic conditions including water depth, reef and underwater obstacle detection, beach composition and slope, and nearshore wave and current patterns is required to effectively project power ashore. In addition, reliable information on enemy defensive emplacements can obviously facilitate maneuver and the selection of operational fires, thereby minimizing casualties.

MSI analysis can provide almost all the necessary operational RECCE in terms of bathymetric data. A recently developed automated program called Fathom, produces relative depth bathymetric image charts from MSI.[21] These are easily calibrated and especially valuable since nearshore bottom conditions frequently change due to storms and currents. In this fashion, Fathom imagery can corroborate older, conventionally charted depths which may be suspect.[22] MSI can also be used to identify potential channels and rip currents by contrasting the turbidity of these areas with the adjacent, undisturbed water.

The conditions of the beach, which of course, significantly impact mobility, can also be gleaned from remotely sensed imagery. TERCAT can identify beach composition by differentiating mud flats with fine grained silt particles from the preferred coarser grained sand beaches. Similarly, the extent of beach width and tidal variation can be assessed by easily tracking the water's edge between high and low tide occurrences. Beach gradient can also be accurately determined by correlating the two-dimensional MSI with precise

satellite radar altimeter data.

Of obvious concern to the amphibious assault planner is the presence of underwater obstacles. Once again, MSI is the correct tool to ascertain these impediments. Both man-made and natural hazards that are hidden under the surface, contrast significantly with the surrounding water column and the background ocean floor in composite MSI. For the CJTF, the combination of bathymetry and beach intelligence will have a significant impact on selecting the best time for an assault as well as the most appropriate craft for the landing.[23]

Naturally, any remotely sensed intelligence that can identify enemy defensive positions that may be employed to repel amphibious landing forces is of the utmost value to the CJTF. Defensive emplacements of troops and equipment are not normally exposed to surveillance. Instead, camouflage, concealment and deception (CC&D) techniques are utilized to deny successful RECCE and exploit the principle of surprise. Fortunately for the U.S. military, MSI now has the ability to overcome enemy CC&D that otherwise thwarts conventional aerial and satellite photographic imaging.

Objects of military significance are typically camouflaged by netting, concealed by cut or live vegetation or painted to deceive photographic and even multispectral sensors.[24] However, by exploiting differences in reflective characteristics, MSI can actually highlight camouflage netting from its background. For mobile objects hidden by cut vegetation, as well as stationary objects such as bunkers that are concealed by live growth, a difference in moisture content from the surrounding foliage (known as vegetation stress) is discernible

in MSI.[25] For a while, scientific ingenuity had defeated detection of objects from space-based infrared (IR) sensors by developing a dull, IR reflective paint which actually emulates the emissive heat signature of vegetation. However, recent analysis has shown this type of deceptive paint to be vulnerable to detection by MSI.[26] Amphibious commanders, who in the past could only guess at the extent of enemy fortifications that were effectively hidden from their conventional RECCE by CC&D measures, are much better informed these days. In this type of scenario, the exploitation of MSI is indispensable in overcoming such enemy deception techniques.

MAJOR REGIONAL CONTINGENCIES (MRCs)

Lieutenant General Moorman, at the time, Commander, U.S. Air Force Space Command, referred to DESERT STORM as:

> "... a watershed event in military space applications because, for the first time, space systems were an integral part of terrestrial conflict and were crucial to its outcome."[27]

The next MRC is certain to follow suit, especially in terms of space-based environmental monitoring for use in the IPB process. In particular, weather forecasting and terrain characterization will be crucial to strike planning, ballistic missile defense and ground combat, just as they were in the Gulf War.

In terms of strike mission planning, on scene weather can have a profound effect on operational fires and RECCE. Since weather satellites are capable of providing a theater level, synoptic meteorological picture on a continual basis, accurate forecasting based on this data can have a direct impact on flight sortie scheduling and targeting. During DESERT STORM, the weather at the start of the air operations was described by many experts as the

region's worst in 14 years. However, there were times that aircraft were able to launch and deliver ordnance in small breaks detected by DMSP imagery.[28] Without this precise weather data, strike missions during such inclement conditions would likely have been scrubbed for the duration of the storms. Favorable weather is also essential for targeting and munitions selection. For today's laser-designated precision guided munitions to work, there has to be a clear view of the target. With accurate weather intelligence depicting which targets are clear and which are obscured, both target selection (which may even have strategic implications) and weapons loading can be optimized.[29]

A correct assessment of atmospheric aerosol content, vertical temperature profiles, and indices of refraction is essential for the modern sensors and platforms that utilize current electro-optical and electromagnetic information. This is especially applicable in the realm of electronic warfare (EW) and missile targeting where factors such as attenuation, refraction, reflection and diffraction all play important roles.[30] For weapons systems dependent upon this type of meteorological data, it can be gleaned from DMSP imagery and directly downlinked to the CJTF for use in both conventional and EW operational fires selection.[31] Another unique theater level requirement that also depends on accurate meteorological monitoring is related to ballistic missile defense. Specifically, it is the potential spread of chemical or biological agents from warheads carried by these weapons. In this case, the meticulous monitoring of atmospheric wind speed and direction (as measured by DMSP) is essential for precisely predicting the dispersion of such agents and

executing the appropriate defensive measures.[32]

Of course, future MRCs are certain to encompass some of the applications addressed in the previous scenarios. With regard to conventional ground combat operations, identifying and defeating enemy CC&D is paramount. Similarly, recognizing and interdicting critical enemy land LOCs is essential for victory. Utilizing MSI generated, 3D perspective views can benefit both air and ground operations. Besides assisting in flight planning, they can also be especially useful in the role of close air support rehearsal. Concerning ground combat operations, the detailed 3D images can help plan the emplacement of weapons, define fields of fire and intimately familiarize armored and wheeled vehicle crewman with the terrain to be navigated.[33] Obviously, the CJTF needs to consider the entire range of military applications of MSI as he endeavors to improve his battlefield visualization and incorporate this environmental intelligence into his decisions on RECCE, mobility, maneuver, deception and fires which are all crucial to the outcome of any MRC.

CONCLUSIONS

Vice Admiral Dougherty, at the time, Deputy CINC, U.S. Space Command, has cited DESERT STORM as:

> "... the first war where the complete range of space systems was integral to operations at the theater level of war".[34]

Part of this unprecedented integration of space systems was realized through the remotely sensed assessment of the physical environment in the Kuwaiti theater of operations, especially in the realm of terrain characterization and weather observation. Continued advancements in satellite technology and environmental imagery analysis capability,

have spurred a similar progression in the area of exploiting such advancements in direct support of military operations.

For operational commanders, the availability of MSI has never been as widespread and accessible as it is today. At the theater level, CJTFs have already demonstrated the capacity to understand the implications of its use in enhancing their overall battlefield situational awareness. The utility of MSI can have a direct bearing on a commander's operational decisions with regard to RECCE, fires, mobility, maneuver and deception. Specific applications including; imagery mapping, bathymetry, terrain categorization, perspective view "flythrus", CC&D detection, weather analysis and even disaster assessment can be implemented across the entire spectrum of conflict with incredible versatility. In fact, innovative MSI analytical capabilities coupled with U.S. space dominance have put today's CJTFs in an unparalleled position of exploiting the environmental conditions of the battlefield to their advantage.

As the U.S. military continues to develop its impressive ability to master the art of battlefield visualization, satellite imagery is certain to remain paramount in this endeavor. Detailed monitoring of the environment from space is just another step in the evolution of the completely digitized battlefield that has been envisioned by several forward thinking warfighters. In the not too distant future, a complete, vertically and horizontally integrated picture of the battlefield, drawn from tactical to national level information systems, should be a reality.[35]

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